14. MAGNET DESIGNS

INTRODUCTION

The lattice consists of conventional dipole, quadrupole and sextupole magnets constructed with hollow conductor water cooled windings and laminated iron pole and yokes. The dipole magnets within the arc sections of each of the four rings are identical rectangular "C" type. Curved magnets are planned for the transition arc from the injector to the main linac. The quadrupole and sextupole magnets are variations on magnets designed and built for the ALS booster ring. To allow for future modifications and design maturation, the magnet designs incorporate a 150% margin on beam energy [1].

The magnet system employs the most mature of technologies associated with accelerators. Despite this, a few of the magnets in the lattice demand relatively sophisticated design and engineering. Other magnets within the lattice can be extrapolated from existing (proven) designs. The spatial constraints as well as the need to allow for future upgrades require that the designs be highly evolved and that the parameters be narrowly defined.

REQUIREMENTS

The accelerator baseline design includes four electron rings with beam energies of approximately 0.7, 1.3, 1.9 and 2.5 GeV. All four beams are accelerated through the same linac and the different energy beams are separated in the horizontal plane before they orbit through their respective rings. The most demanding magnet designs are those in the separator and combiner sections where the separation between beamlines is small resulting in requirements for septum styled dipoles and quadrupoles (see Figure 14-1). The leakage field from the septum magnets to the adjacent beamlines must be quantified and reduced. An upgrade to a final energy of 3.1 GeV is anticipated but this falls well within the 150% margin applied to the baseline final energy.

Although the fields and gradients of the various magnet types are modest for the baseline beam energy, in addition to having to deal with pole and yoke saturation effects, the 150% field margin represents a >225% power increase with similar demands on the cooling circuits. The ability to operate at 150% of the baseline energy requires a more complete and detailed magnet design than the "generic" geometries typically used in *zero-order* conceptual designs. Consequently, the magnet designs presented in this document reflect a greater amount of engineering than is typical of a concept at this point of development.

The total power requirement for all lattice magnets for the facility is approximately 2 MW. Details of coil package and magnet power supply requirements are to be found in the references at the end of this chapter.

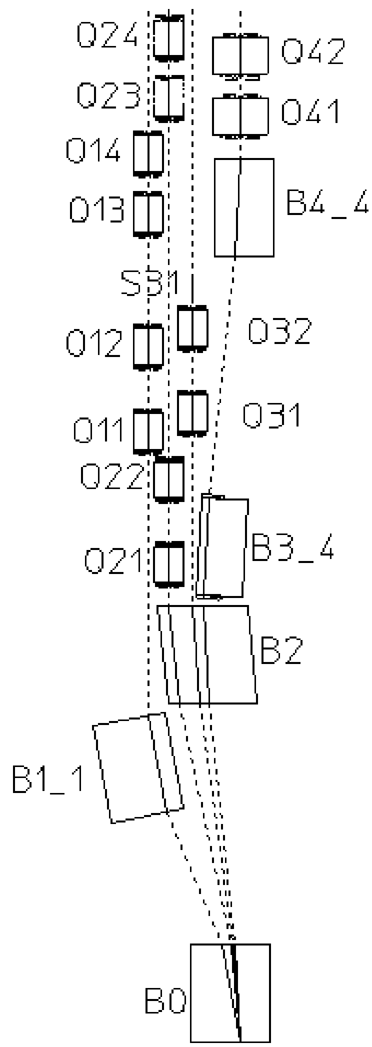


Figure 14-1 Magnets in a beam spreader region. The linac is at the lower end of the diagram, and the four rings continue at the upper end.

Field Quality

At present, the field quality requirements are not completely specified for each magnet type. Therefore, field quality requirements for magnets employed in a typical third generation synchrotron radiation storage ring have been used as *achievable* goals. This should be adequate since the stringent field quality requirements for storage rings with a beam lifetime of many hours are typically more demanding than for most other accelerators.

SEPTUM DIPOLE (B3_4)

The septum dipole, shown in Figure 14-2, is the most demanding of the magnets [2]. The limited space between the 1.9 and 2.5 GeV beamlines requires a high current density in the septum. At 150% the nominal energy, the water circuit topology requires one water circuit per turn. Detailed POISSON calculations have been performed to evaluate both the field uniformity in the gap as well as the leakage field in the adjacent beamline with an iron shield inserted in the narrow 4-mm space between the magnet and the 1.9 GeV beamline.

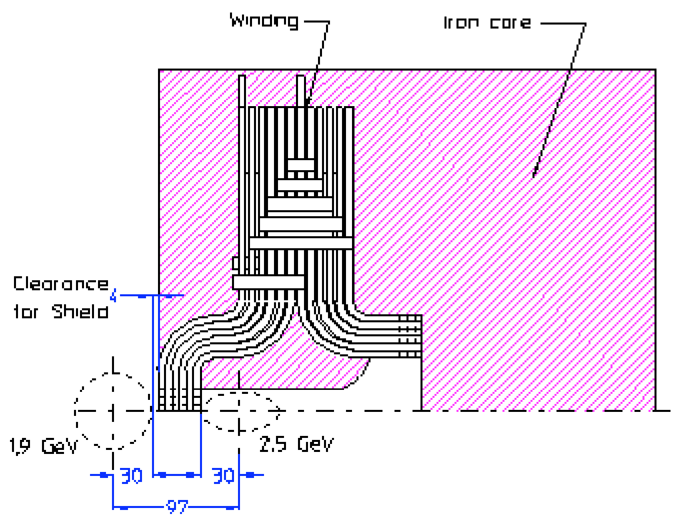


Figure 14-2 Septum Dipole Magnet.

SEPTUM QUADRUPOLE

The septum quadrupole used in the combiner and spreader sections, shown in Figures 14-3 and 14-4, employs a *figure-8* desig*n* [3]. The 7.64-mm space between the edge of the magnet and the adjacent beamline will be utilized for magnetic shielding, although the narrow vertical leg provide some shielding. Since magnet requirements vary widely, two variations are used, one with half the number of windings than the other.

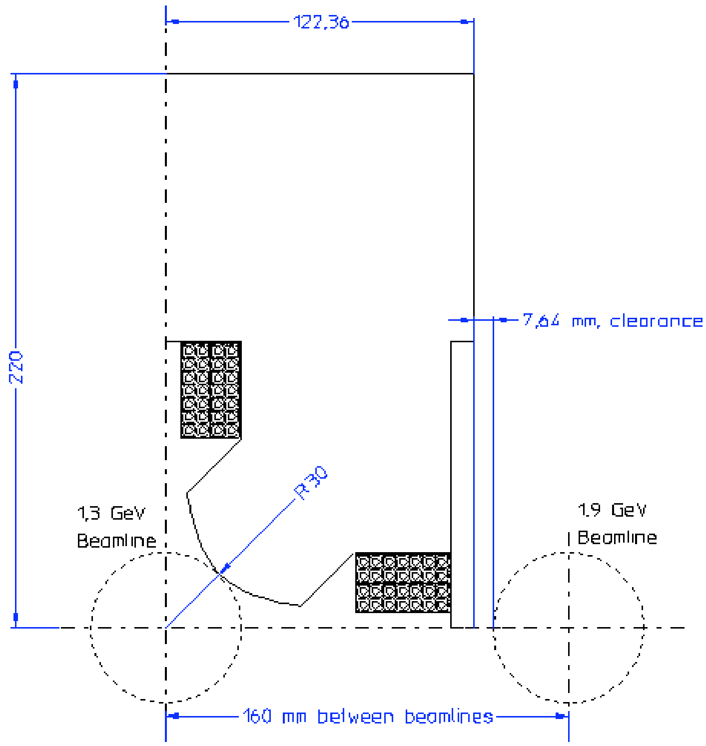


Figure 14-3 One quadrant of a septum quadrupole magnet in cross section.

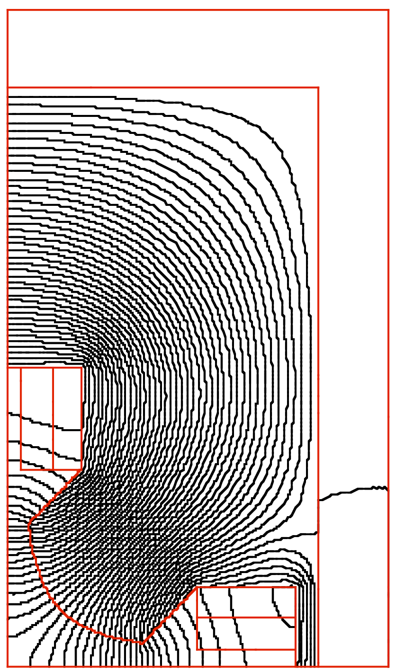


Figure 14-4 Plot of magnetic field lines for septum quadrupole.

MAIN RING BENDS

Longitudinal and transverse spatial constraints result in a *tall* coil package and a narrow pole [4,5]. To meet a large dynamic range requirement, good field uniformity needs to be maintained from <1 T to >1.5 T.

A layout of the lattice at the entrance to the arc sections is shown in Figure 14-5. The baseline geometry is constrained by the 17.5 mm half sagitta for the softest (0.7 GeV) beam. The 15-mm half aperture, including a reasonable pole overhang to assure good field quality, results in the pre-optimized pole geometry shown in Figure 14-6. The coil shape has been determined by requiring a reasonable current density to minimize power consumption. This results in a fairly steep pole-edge angle.

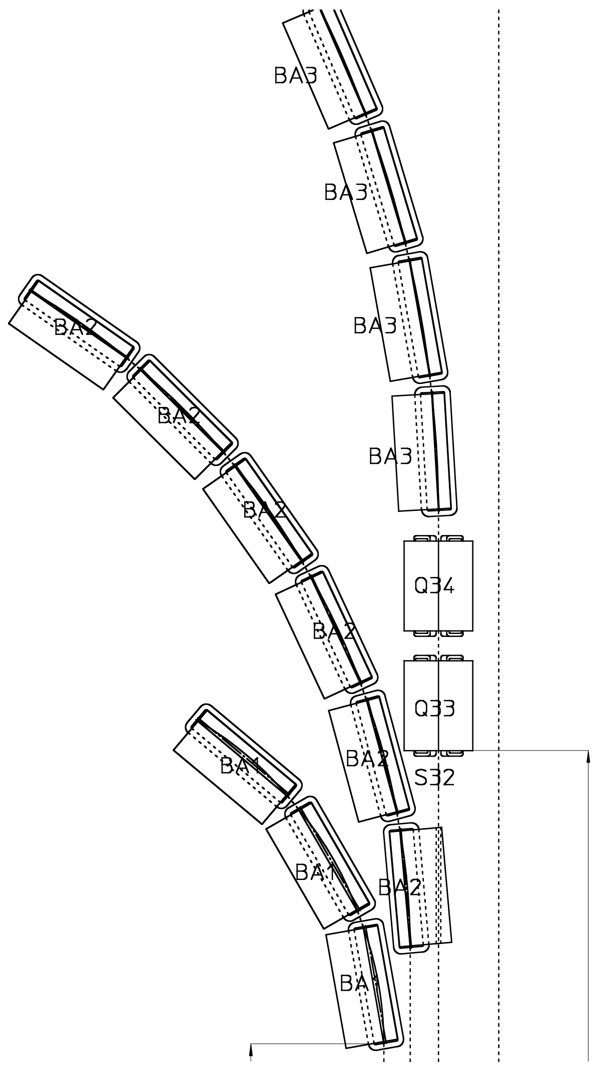


Figure 14-5 Magnet layout at the entrance to the ring arc sections. Bend magnets in the arcs are denoted BA.

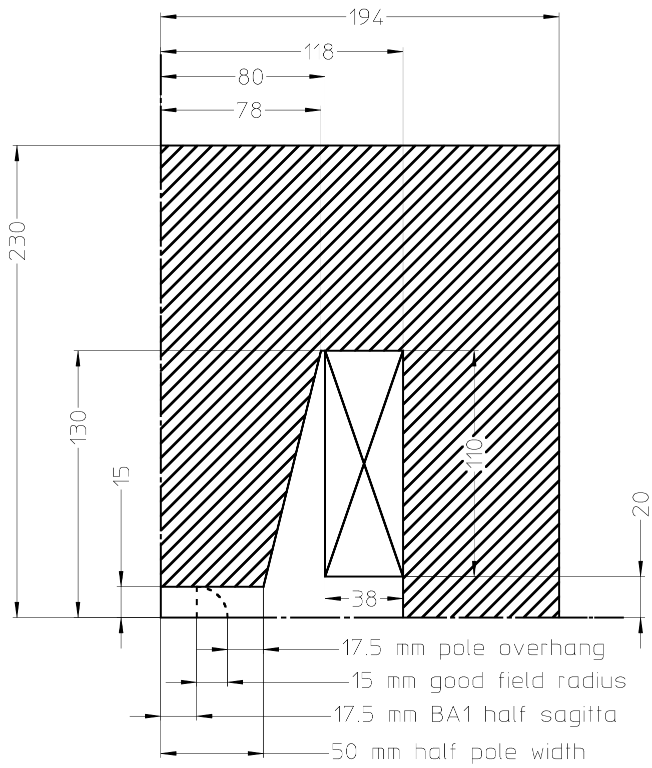
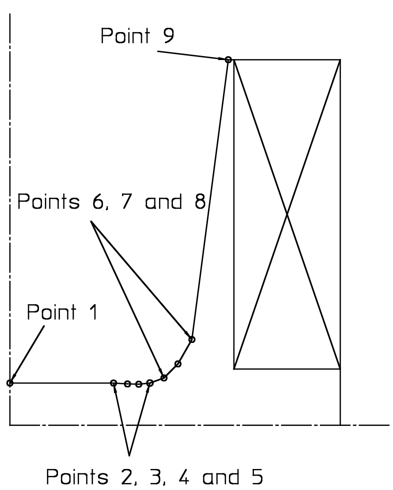


Figure 14-6 Starting geometry for bend magnet pole optimization.



Points	X (mm)	Y (mm)
1	0	15
2	37	15
3	42	14.7
4	46	14.6
5	50	15
6	55	16.82
7	60	21.82
8	65	30.48
9	78	130

Figure 14-7 Dimensions of an optimized arc bend magnet pole.

We have placed a radius on the pole corner in order to maintain field uniformity throughout the full range of excitation (a sharp pole corner tends to *disappear* as it saturates at high field). Finally, amplitudes of selected points on the pole were adjusted until good field uniformity is achieved at both low and high excitations.

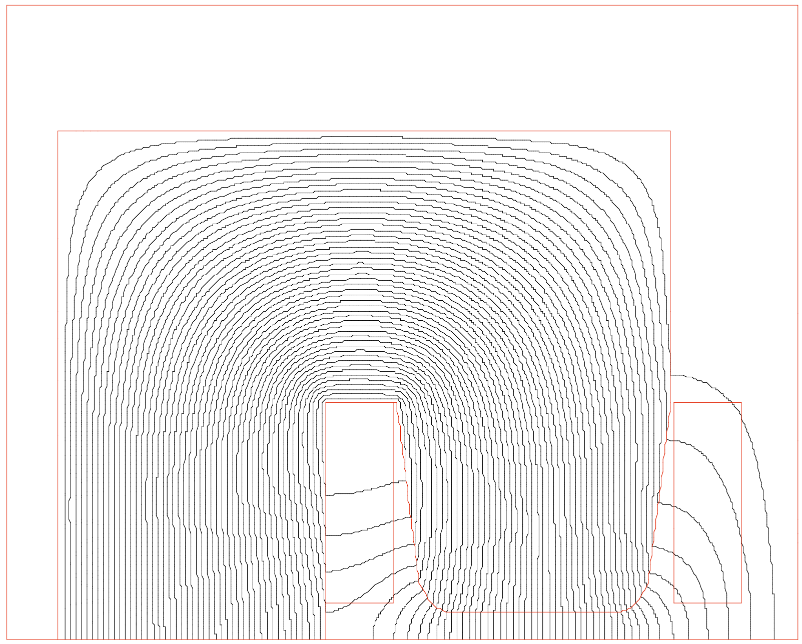


Figure 14-8 Magnetic field plot for an arc dipole magnet after pole shape optimization.

Main Ring Quadrupoles

The yoke design for the main ring quadrupoles is patterned after the ALS booster and booster to storage ring quadrupoles [6]. It is anticipated that the same die set used to stamp the laminations for these magnets can again be used. The coil design is patterned after the storage ring quadrupole coils, using small conductors so that low-current power supplies may be used.

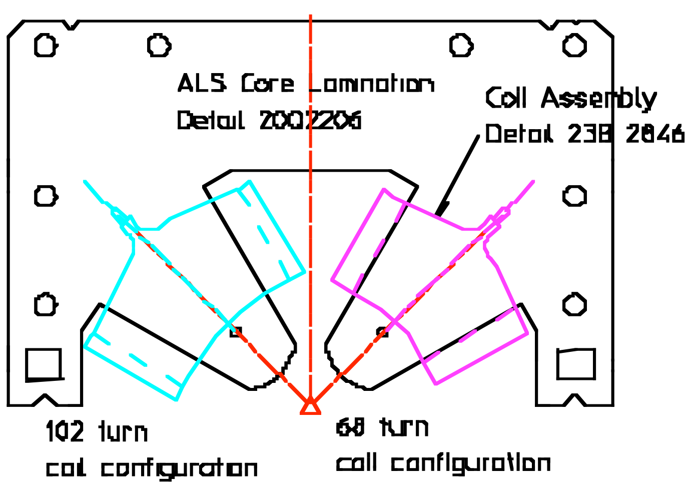


Figure 14-9 Yoke and coil configuration of the quadrupoles for the ALS booster.

MAIN RING SEXTUPOLES

The sextupole core laminations use the same shape as that of the ALS booster sextupoles [7]. The 32-turn coils are wound using hollow conductor and are tall and narrow to fit between adjacent poles. Figures 14-10 and 14-11 show the cross-sectional (half) view and a magnetic field plot of a 1/12 segment.

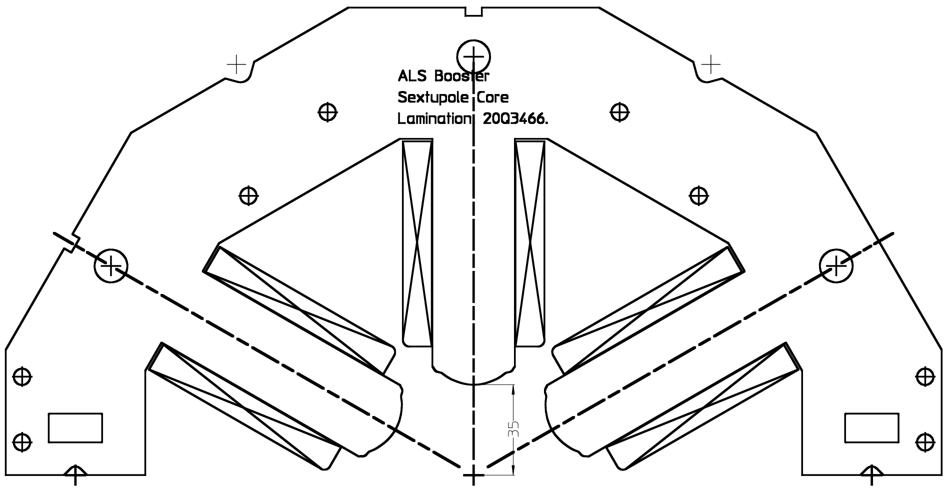


Figure 14-10 Cross-section of a lamination of the ALS sextupole design.

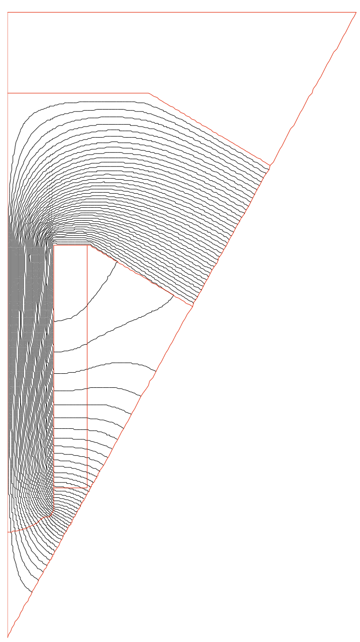


Figure 14-11 Magnetic field plot of ALS 1/12 sextupole magnet.

REFERENCES

[1] J. Tanabe, "Recirculating linac magnet designs summary", LBNL Eng. Note M8153, November 2001.
[2] J. Tanabe, "Recirculating linac spreader magnet designs", LBNL Eng. Note M8151, November 2001.
[3] J. Tanabe, "Recirculating linac septum quadrupole designs", LBNL Eng. Note M8157, November 2001.
[4] J. Tanabe, "Recirculating linac spreader main bend magnet coil designs", LBNL Eng. Note M8154, November 2001.
[5] J. Tanabe, "Recirculating linac main bend core and pole designs", LBNL Eng. Note M8155, November 2001.
[6] J. Tanabe, "Recirculating linac main bend core and pole designs", LBNL Eng. Note M8156, November 2001.
[7] J. Tanabe, "Recirculating linac main sextupole design", LBNL Eng. Note M8152, November 2001.